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Analysis of Firefighter Response Time Utilizing Arc GIS Network Analysts at Puchong Fire Stations in Malaysia

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Abstract: Malaysia's fire department strives to ensure effective mitigation of property damage and loss of life through efficient and methodical operation of its services. Fire control services are essential services in any civilization that aim to save lives and property. The Puchong fire station is an exemplar that offers services and help in the realm of creating, developing, and implementing strategies aimed at ensuring high-quality firefighting operations. The aim of this study was to perform a thorough investigation of station accidents using a collective assessment. The functional classification methodology was used to utilize the pick by features technique to assess response times at four intervals. Geographic Information System (GIS) technology is an emerging tool that is assisting the fire department in optimizing emergency services. Both geographical and non-spatial data are employed after assessing their validity and dependability to analysis the data. The study found that four major routes (Jalan Intan1, Jalan Intan2, Jalan Wawasan3 and Jalan Wawasan5) necessitate a shorter response time, namely within 20 minutes, due to the fact that the response speed of fire stations in the regions affected by those streets was around 71%. In order to address future fires, the study suggests building more fire stations near previously recognized routes, as there are now gaps in the response time to fire events.

Keywords: GIS Network, Fire Stations, Spatial Key Performance Indicators (SKPIs), Puchong.

INTRODUCTION

The Deputy Director General of the Malaysian Fire and Rescue Department emphasized the importance of time in his address titled "Malaysian Fire and Rescue Department: In the Past, Present, and Future in Front" in January 2, 2002. There is less of a chance of rescue by the Fire Department as more time passes after the first occurrence. There are more costs associated with battling the fire because of the delay since more time has passed. In addition, the Director emphasized that the

difficulties of locating fire stations in key locations and the current lack of sufficient fire stations in all nations are major factors in the time it takes for help to arrive during an emergency. Because of their strategic placement, fire stations are often situated in high-crime neighborhoods (https://www.bomba.gov.my/berita/, 2022).

Procedures, resources, and personnel all have a role in how well an emergency response is executed. It is important to identify what services are needed throughout the response, readiness, and recovery phases based on the agencies that are called into action and the specific sorts of crises that occur (Weidinger, 2022). In addition, an event may be mitigated with the use of proper resource management methods like activating an emergency response plan (Olugbade, Ojo, Imoize, Isabona, & Alaba, 2022). That is to say, when there is a crisis or a security issue at the site, it is these trained professionals who are there to deal with it. Emergency medical technicians and firefighters are two examples of professionals in this field (Bjelland, Njå, Heskestad, & Braut, 2021).

The initial reaction time was quantified as the interval between the instant the distress call was received and the moment the fire engine commenced its departure from the station. As per the regulations stipulated by the Malaysia's Fire and Rescue Department (MFRD), the initiation of the fire truck's departure from the station is regarded as the fire engine's optimal speed with respect to its transition from a stationary state (Ni, Arab, Nordin, Hassan, & Witchayangkoon, 2020). In order to provide a practical measure of success, the distance was assigned a weight corresponding to the first emergency response time. The calculation of the weighted initial reaction time to crises included determining the time required per meter for each individual response, which was then averaged based on the total number of events(Sakellariou, Samara, Tampekis, Sfougaris, & Christopoulou, 2020). The average first emergency response time was calculated over a period of five months in order to mitigate any observed variations in the recorded initial emergency response for specific months or incidents (Shakil & Abdul Wahab, 2023; Voytyuk, Kopteva, & Skamyin, 2021).

"We've identified a number of trouble spots that take more than 10 minutes to reach by foot. There are delays in our ability to get there quickly. This necessitates a fresh look at how to make it better. It all depends on administrative borders and how far the fire station is from the incident. We used these two systems to send out fire engines from two different stations. If there were a fire in Manjoi, for instance, we would send firefighters there from Ipoh and Meru. We're simply trying to get there as quickly as possible". (Daim, February 23, 2017)

According to (Marras & Karwowski, 2021; Podawca & Pawłat-Zawrzykraj, 2021), The timeliness of response has significant importance in the context of firefighting. The dynamic nature of land use and urbanization necessitates an ongoing assessment of the geographical distribution of fire risk and fire stations, taking into account the benefits and the associated costs. Given the geographical nature of these problems, Geographic Information Systems (GIS) are being used to address and provide assistance for them.

Because GIS is the foundation upon which this subject rests, it is important to first define and then explain what it is. The meaning of the acronym "GIS" might change depending on the level of technical knowledge and the granularity of the data being analyzed. Geographic information systems (GIS) are computer-based systems that are designed to work specifically with spatial data. Using GIS technology, researchers have been able to gather, store, and display geographical data since the early 1970s (Nuthammachot & Stratoulias, 2021).

To date, no research has been undertaken on the examination of response times using Geographic Information System (GIS) technology in relation to the Malaysia's Fire and Rescue Department (MFRD). This research aims to position us as pioneers in the field of technological advancements and meet the newest standards.

METHODOLOGY

Incident Data

The Malaysia's Fire and Rescue Department (MFRD) operates around 33 fire stations throughout the state of Selangor. Each fire station is assigned its own administrative border, referred to as the "Station Ground." The decision to use Puchong Fire Station as a case study relied on several factors. One of the factors contributing to this observation is that the Puchong Fire Stations ranked second among all fire stations in Selangor in terms of the highest number of emergency calls received in 2022, with the Kajang Fire Station taking the lead. With one of the highest populations in Selangor, apart from Subang and Petaling Jaya. Puchong's opposition to one of the considerations played a role in their selection. Table 1 presents data on the Population, Density, and Area in Puchong City.

Table 1: Puchong City, map of population density.

Puchong City		
Area of City	Population in 2022	Total Population Density
51.71km^2	> 400,000	> 6,486.54/km2

The Office of Petaling's own zone helped gather the necessary information about the incident at Puchong station. Which station in Puchong is managed by the Petaling Zone Office. We owe a great debt of gratitude to the zone shah of all employees who contributed to the realization of this survey. In this analysis, the study only considered fires that occurred in structures, in forests, or in trash bins between January 2022 and December 2022. Table 2 displays information about when the fire began in the time interval mentioned before.

Data recorded in 2022													
Month	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
FireIncident Number	18	26	37	44	26	32	33	38	25	29	17	13	338

Table 2: Fire Station of Puchong Incidents in 2022 Data.

Technology

The ArcGIS 10.8 Series Network Analyst add-on is included in the analyzed software. Microsoft Excel was used to do elementary statistical calculations and to prepare the data for use in GIS programs.

Collection Data and Preparation

The data collected for this study was obtained from the Petaling's Fire and Rescue Service, which serves as the central headquarters for the Petaling's Fire and Rescue Service. The dataset comprises information regarding the emergency response time for each fire incident that occurred in 2022. The document included crucial details such as the address, date, and time of the fire engine's departure, as well as the time of its arrival at the incident location. Additional information fields were included to facilitate the process of inputting data into ArcMap. The data provided encompasses the entire duration of the response in minutes as well as the geographic coordinates of each event location represented in decimal degrees.

ArcGIS was employed to digitize the Fire Station's location from Google Earth, and OSM shapefiles

were downloaded from Open Street Map and used to create a network dataset. The limitations of speed were then added to the network dataset based on the road types, as these are necessary for computing emergency response times.

GIS Technology

Road Network

The study commenced in ArcCatalog with the creation of Highways data using model transportation, namely the Network Analyst extension. The base for the building of a new network dataset was the OpenStreetMap road data collection for Kuala Lumpur. The Network Analyst extension encompasses a range of tools that facilitate the computation of the most efficient path, identification of the nearest facility, and determination of the circular coverage regions for station services. In addition, time and distance attributes have been applied (in minutes and meters, respectively), and evaluator fields have been matched to those in the original dataset. This data set was developed using the Fire Engines Manual for emergency vehicles in Malaysia, which allows for speeds of up to 90 km/hr. Expert opinion and posted speed limits were used to determine speed zones. Table 3 lists the speed limits for all road categories that a fire engine can travel on.

Table3:Maximum Allowable Response Time in ArcGIS Simulation.

KindofRoads	Motorway, Trunk,Primary	Road,MotorwayLink,Unclassified	Trunk Link, Secondary,SecondaryLink, Tertiary, Tertiary Link, PrimaryLink	Residential	LivingStreet	Service, U-turn
AssignedSpeed Limit **(km/hr)**	90	80	70	50	40	35

Certain road types were eliminated due to their inability to be navigated by the Fire Engine. The deleted road types encompass many categories such as footway, light-rail, rail, racetrack, bridleway,monorail, path, pedestrian, stairs, track and subway, as well as a limited number of non-traversable service roads. Both the causes and the most recent available information point to a dire situation on the roads. After cleaning up the road network dataset, it was imported into ArcMap. The incidents that occurred at the Fire Station of Puchong and other fire events in the year 2022 were geocoded utilizing the longitude and latitude parameters. Instead of using an address detector, the study used the latitude and longitude attribute fields to create charts for: (1) the fact that many accidents occurred in places other than at addresses, such as "behind a house," and (2) the fact that the addresses for several incidents were misspelled. Fire station sites (as seen in Figure 1) were mapped with incident data and road network data sets.

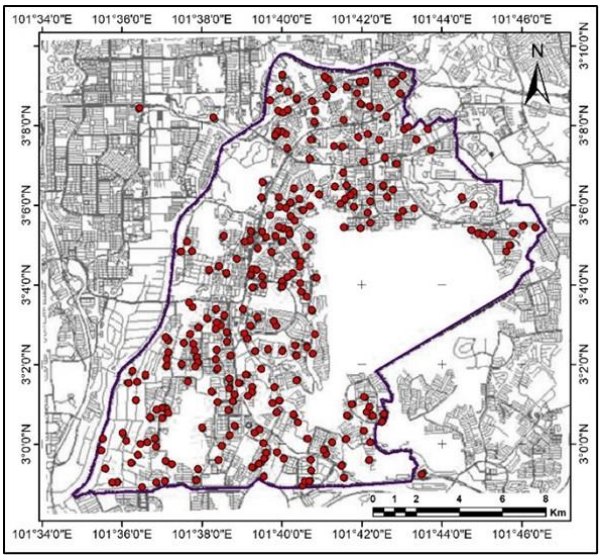


Figure1:Red dots represent fires and the purple polygon represents the Puchong Fire Station

Service Area

The network analysis calculated service regions with a 10-minute response time using data from the road network's emergency services. The location of fire stations was utilized as a point of reference for establishing a graphical selection. This selection was made after using abilities and analysis sets to determine the time served as the value of impedance. Additionally, a stopping value of 10 min. was set, the path was fixed to avoid U-turns, and the facility was enabled. According to (Lee, McDonald, Montgomery, & O'Neill, 2021) Additional options were provided to allow for the retrieval of detailed polygons, aggregate properties, and distance and time line generations. The spatial key performance indicator (SKPI) of the MFRD response time was used to categorize the 10-minute service zones.

Closest Facility

The nearest Facility technique was frequently utilized in the network analysis for determining travel times to event locations. Fire mishaps at both the plant and the station were recorded; hence, the latter was added as the occurrence site. Time was specified as the value of impendence in the research sets, transportation was accounted for in terms of talent to incident, and U-turns were permitted. Additionally, cumulative attribute settings were implemented for both the time and distance that are returned. Using these tactics, researchers found the most efficient route from any event site to the nearest fire station.

The results outline the most efficient route for each occurrence and have constructed a comprehensive database with attributes such as distance and time for each incident. The aforementioned observations solely provided information regarding the duration of transportation to event locations. Consequently, a new factor was introduced to account for the additional time required for attendees to arrive at the event venues, resulting in an updated estimate of one minute. Figure 2 illustrates the incident response times and routes predicted using Geographic Information Systems (GIS) in the context of the Puchong Fire Station.

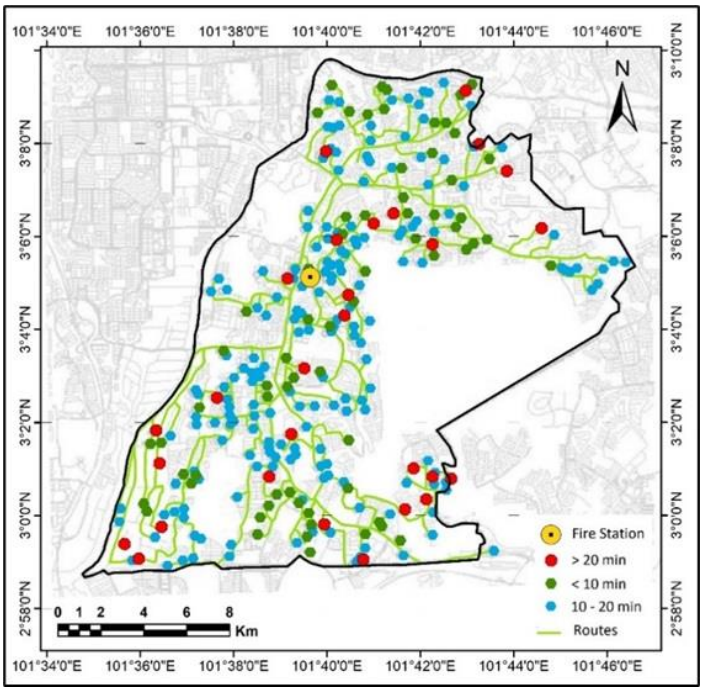


Figure2:Problems in the Network Located in Puchong, Malaysia, the Puchong Fire Station responded to 338 separate fire incidents.

Detailed of Service Area Incidence Anlysis

In this analysis, events were queried using GIS service regions and the Pick by Location technique within those areas. Protocol selected both actual accidents and GIS simulations for investigation by the Puchong Fire Department. The objective of this study was to conduct a comprehensive analysis of station accidents through an aggregate evaluation. The results were disseminated using a functional classification approach, employing the Pick by Features method to measure response times at four-minute intervals. Subsequently, those events were once again dispersed into novel functional groups. The significance of this study lies in its provision of a comprehensive listing of accident occurrences inside service areas as well as those that transpired beyond a ten-minute radius. Based on the provided information, this study has identified specific areas of concern that elucidate instances where anticipated response times are not met.

Area of Concern Analysis

The analysis of feature class data was conducted as part of this study to examine incident response times that exceeded a duration of ten (10) minutes. The study identified geographical regions characterized by a high concentration of accidents and provided an explanation for the

occurrence of densely populated areas with a high volume of emergency calls. The study's findings identified several regions within the Puchong Fire Station's jurisdiction that raised concerns. The results revealed that these areas saw response times exceeding ten (10) minutes, coinciding with the occurrence of many accidents.

Statistical Analysis

This study began by contrasting the actual response times supplied by fire departments with those predicted by a Geographic Information System (GIS) model. Excel's frequency analysis function was used to perform the statistical analysis, yielding the mean reaction time and the 90th percentile value. Information classification underpins the use of the 90th percentile as a criterion for assessing the timely value of answers. If the goal is to respond to 90% of occurrences within 10 minutes, this defines the point at which the success criteria are reached.

Comparative Analysis

The purpose of the study was to compare and contrast the GIS event data with the actual incident data. In order to compute the sum of occurrences across time, the reaction time characteristics were analyzed and chosen. The findings provided a detailed evaluation and explanation of the response times under the actual circumstances.

RESULT AND DISCUSSION

Comparative Analysis Results

The findings of the comparison study indicate the potential for significant enhancements. The significance of this research lies in its examination and comparison of response time data pertaining to the analysis of station response time and the analysis of service area incidents.
In the case of the Puchong Fire Station, a comparison was made between the response times seen in real-life occurrences and those predicted by the GIS model. The conclusions of the study established the key temporal factors, event aggregates for various temporal intervals, and the variability within the dataset. The results are succinctly presented in Table 4 and are shown as follows:

Table 4: Analysis results for Fire Station compared with others in the table by using the CR column.

Fire Station Analysis	Actual	GIS	CR
Total Incidents	338	338	0
Avg. Time	12.50	10:58	1:52
90th Percentage	20:00	18:50	1:10
<5 min.	30	58	28
5-10 min.	122	86	36
<10 min. (A)	162	144	18
10-15 min.	115	107	8
15-20 min.	30	53	23
10-20 minute (B)	145	160	15
<20 minute	291	304	13
>20 min. (C)	33	22	11
Total within 10 min.	163	143	20
Total within 20 min.	291	305	14
Response per.< 10 min.	50%	44%	6 %
Response per.< 20 min.	91%	95%	5 %

The results for the Fire stations of Puchong indicate that the GIS average time is 10 minutes and 58 second, an improvement of 1 min. and 52 sec.; that the 91th percentage time is 10 min. and 58 sec.; that the total number of calls answered in 20 minutes is 304, an improvement of 14 calls; and that the station's service is 95%, an improvement of 5% for calls lasting less than 20 minutes.

Service Area Results

The new Puchong Fire Station service area was approximated using GIS data. The results outline the places and highways that a fire truck can reach in less than 10 minutes. The results provided a more accurate depiction of the region covered by the Puchong Fire Station. Figure 3 depicts a service area with a response time of 10 minutes that covers 28 square kilometers. In addition, a Spatial Key Performance Indicator (SKPI) for MFRD depicts response time zones by Service area: Value intervals of 5, 10, 20, and > 20 Minutes (Table 4).

Figure3:Area Covered by a Ten-Minute Response Service

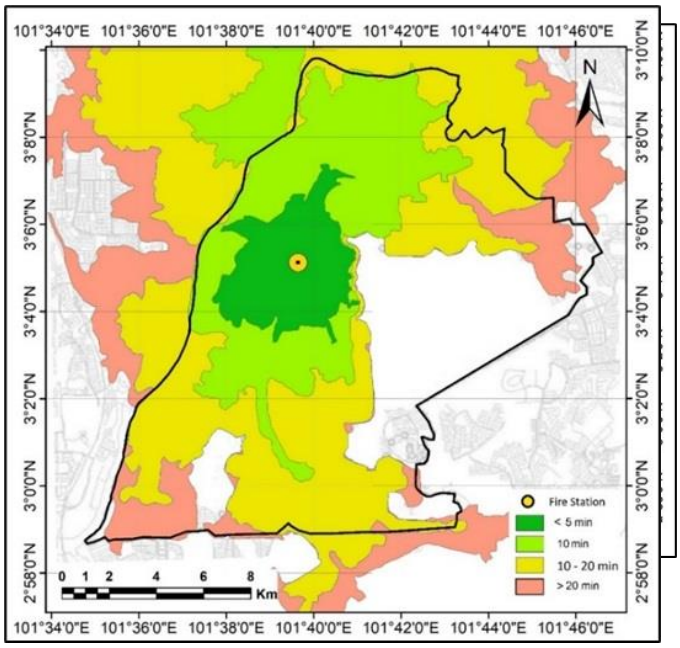


Figure 4: Spatial Key performance indicator (SKPI) for MFRD, dividing service territory into zones based on response times (5 minutes, 10 minutes, 20 minutes, and > 20 minutes).

Detailed Results for Service Area

The examination of results focused on events that occurred within the designated service area as well as occurrences that were accompanied by a response time of 20 minutes. These results were employed to ascertain the areas of concern. Figure 5 provides a visual representation of the area served by the Puchong Fire Station, illustrating the occurrences of genuine accidents within a 20-minute time frame (shown by red dots) and the events that have actually been attended to within the service area (represented by blue points). The observed occurrences during a span of 20 minutes are visually represented as red dots, whereas the genuine instances inside the service area are depicted as blue points.

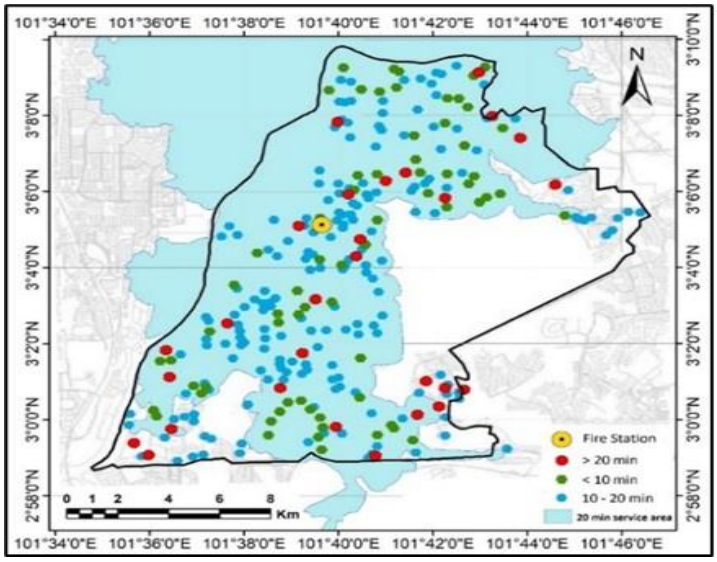
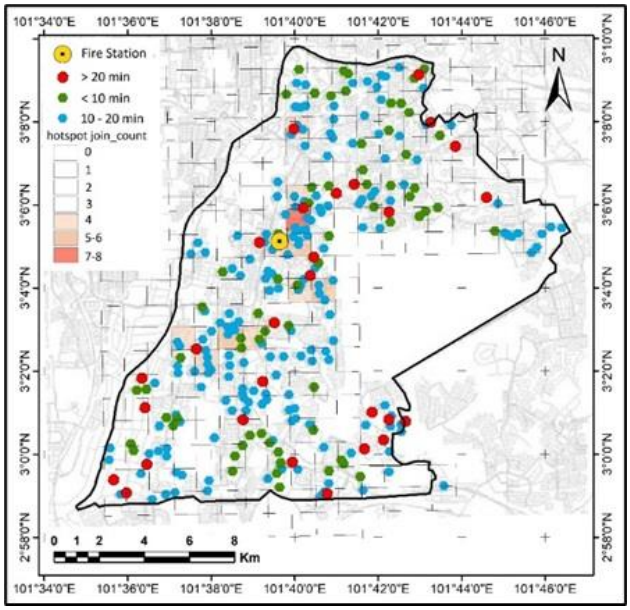


Figure 5:Utilizing service area incident analysis to develop service area areas of concern

Results for Area Concern

The study's findings pinpointed locations where responses often took more than 20 minutes. Of the total number of instances, 8, or 29%, were primarily focused on the areas of concern for the actual data provided. In Figure 6, the potential problem region was pinpointed. The following routs have the main issues that need a reaction time of fewer than 20 minutes: (Jalan Intan1, Jalan Intan2, Jalan Wawasan3



and Jalan Wawasan5).

Figure6:Concern Area Results

Discussion

The study consists of a simple examination of emergency response times, and the results indicate certain ways in which the Puchong Fire Station may benefit from using a GIS. The research used actual emergency event locations and reaction times to mimic theoretical GIS computations of response times. This validated a comparison of real and GIS-modeled reaction times, where the results indicated

significant shifts in response dependent on the use of GIS software.

The conventional method for getting to accident scenes is to use major thoroughfares. The GIS model went farther than the traditional method by evaluating the travel time of each road segment, which allowed for faster responses to incidents, the identification of the most expedient routes to each occurrence, and an overall boost in division of emergency management efficiency.

The community can gain a deeper insight into service capacity in terms of response times thanks to the findings of future coverage regions. The comparison research of reaction times between actual tools and GIS tools revealed that, station-by-station and across-the-board incident reports, model-based response periods for the hypothetical GIS were shown to significantly increase the overall response times. The results pertaining to the areas of concern identified by the AIDS study delineated the specific areas that exhibit potential for enhancement in relation to emergency response time. Therefore, the implementation of community-based emergency response strategies can enhance the resilience of specified places in the face of disaster situations.

Conclusion

This research used Geographic Information System (GIS) research methods to pinpoint significant improvements in response times across the board for the Puchong Fire Station's full-service area and accomplishments.

At the chosen levels of analysis, the information reveals potential regions for response enhancement and new service areas determined by station response time output levels, response times, and the advantages of using GIS technique in the response process.

Geographic Information System (GIS) analysis gives the dataset value in terms of understanding and response time and has the ability to evaluate said data in order to find success indicators. Geographic Information System (GIS) software enables the examination of arrangements to transition from being a sporadic occurrence to a systematic process.

Effective explanations of problem regions and alternatives can be gleaned through GIS analyses. Accurate data like this will provide an incident superior with the knowledge and ability to foresee how long it will take to allocate resources for various emergency procedures. It will offer accurate data for a superior situation to make important judgments, such as estimating how long it will take to distribute resources among various rescue efforts.

The fire department utilizes highly effective Geographic Information System (GIS) software in order to optimize resource allocation, improve the quality of service provided, reduce the number of casualties, and boost the level of protection for firefighters. This can be organized into distinct phases or via the use of a project management framework. The strategic decisions made by the Malaysian Fire Department will enable it to effectively grow and adapt using a structured policy framework and long-term goals.

Due to the large number of variables, this study may be subject to limitations and sources of inaccuracy. Time of response was a primary focus of the study; however, other factors such as train traffic, weather, traffic density, construction projects, and road placements were overlooked throughout the network analysis.

The results may also be affected by other factors that were not tested for, like the total number of emergency calls or the severity of incidents. These factors may be used in the future to conduct a more in-depth examination of emergency response times. The research was done separately from any other fire stations in the area.

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